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IMPACT OF COW SIZE AND VALIDATION OF AN ELECTRONIC FEEDER TO OPTIMIZE RESOURCES IN BEEF PRODUCTION SYSTEMS

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IMPACT OF COW SIZE AND VALIDATION OF AN ELECTRONIC FEEDER TO OPTIMIZE RESOURCES IN BEEF PRODUCTION SYSTEMS

by

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IMPACT OF COW SIZE AND VALIDATION OF AN ELECTRONIC FEEDER TO OPTIMIZE RESOURCES IN BEEF PRODUCTION SYSTEMS

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Optimizing beef production systems is critical in the longevity of an enterprise. In a time of rapid change and innovation, there are increasingly more opportunities to improve efficiency of livestock production by taking advantage of new technologies. Furthermore, production environments vary drastically in all segments of the beef industry, which influence feed resource availability. Therefore, it is critical to realize the cow type that excels in a given production environment according to management objectives. To gain a better understanding of the optimal cow type in the Nebraska Sandhills, a retrospective analysis was conducted to evaluate increasing cow body weight (BW) on cow performance, steer progeny performance, and heifer progeny performance. As cow BW increased, the ability to maintain BW and body condition score (BCS) from pre-calving to weaning increased. Pregnancy rates were improved in larger-sized cows. As cow BW increased, steer progeny had increased BW at weaning, at feedlot entry, and greater hot carcass weights with minimal impact on carcass quality. Increasing cow BW also increased heifer progeny weaning weights, post-weaning BW, pre-breeding BW and BW pre-calving; however, heifer progeny reproductive performance was not influenced by dam BW. In a hypothetical scenario using regression data, smaller-sized cow herds may have increase total production output of calf BW at weaning and cull cow BW.

Innovative electronic feeding systems may provide an advantage to monitor cattle and deliver supplement more consistently increasing beef production efficiency. Two validation studies were conducted to quantify the acclimation period associated with the introduction of an electronic feeder to naïve cattle. In experiment one, (13%) of the cows did not use the feeder over a 23 d test period. In experiment 2, (7%) of heifers did not use the feeder over a 14 d period. In both experiments, as ambient temperature decreased, supplement intake tended to decrease. Cows most frequently visited the feeder early in the morning after sunrise. A better understanding of the cow type and supplement delivery technology that optimizes resources and animal behavior could improve efficiency in livestock production.

Keywords: beef production, cow size, production efficiency, technology

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CHAPTER I. REVIEW OF LITERATURE

INTRODUCTION

Increased demand for food worldwide, cost of production, and scarcity of land and feed resources has scientist and livestock producers evaluating management practices to optimize available resources. Technology has increased food production efficiency while using fewer resources; however, there is increasingly more opportunities to enhance production efficiency with new innovations. Advancements have come through technologies in nutrition, reproduction, growth promoting enhancement products, feed additives and feed delivery systems (Drouillard, 2018). However, continued viability of range-based grazing systems requires more rapid adoption of innovative management practices (Mulliniks et al., 2015).

Utilizing strategic supplement strategies that incorporate new technologies, such as feed delivery systems, may provide opportunities to further enhance the efficiency of range-based production systems. Technologies related to cow-calf enterprises should incorporate strategic supplementation strategies that are cost effective and maintain or enhance animal performance. Providing a supplement delivery system that optimizes economic inputs may effectively improve the efficiency of beef cattle production systems (Wyffels et al., 2018).

In addition to supplementation strategies, optimizing growth potential in a given environment and production system may provide the opportunity to increase resource efficiency. Cow size has been shown to impact production in differing production environments (Olson et al., 1982; Scasta et al., 2015; Beck et al., 2016). Differences in geography and climatic conditions are dependent upon a broad spectrum of animal phenotypes that are best suited to these environments (Drouillard, 2018). Understanding the cow type that most efficiently utilizes the resources in a production environment varies and deserves selection attention of each individual ranch (Mulliniks et al., 2015). The research in this thesis described efforts at the University of Nebraska-Lincoln strive to determine the impact of cow size on production efficiency and validating an electronic feeding system in the Nebraska Sandhills.

IMPACT OF COW SIZE ON COW-CALF PRODUCTION

The optimal size of cattle has been debated among producers, scientists and cattle breeders for many years (Arango and Van Vleck, 2002). There is a continued need for cattle populations that vary in size and rate of maturing and no single size will be most efficient in all production scenarios (Klosterman, 1972). Cartwright (1975) recognized the segregation of beef production including cow-calf, backgrounding/stocker, finishing and packing and pointed out efficiency in one segment does not equate to efficiency of another segment. Smith (1979) suggested cattle should be selected with the greatest size to produce slaughter cattle of the heaviest acceptable market weight. Buttram and Willham (1989) suggested small cows are more favorable because of their increased calving rate, cycling rate, and conception rates compared to medium and large cows. Further complicating the debate, production conditions are dynamic and cyclic so size preferences remain in continuous disequilibrium (Cartwright, 1979).

Mature cow size has implications with production parameters associated with the cow herd. Heifer development, cow reproduction, and calf performance are all influenced by mature cow BW (Hersom, 2015). Additionally, cow size impacts all segments of the beef industry from transportation, to processing, and retail (Scasta et al., 2019). Trends in mature cow size have been reflected in the carcass weight of slaughter cows over the past 44 yr. The trend in cow carcass weight shows a steady increase in the BW of slaughter cows on a dressed basis ranging from 215 kg in 1974 to 293 kg in 2018 (National Agriculture Statistics Service, 2019). It is thought that the increasing trend in cow size is attributed to market signals for meat yield because of consumer demand (Notter et al., 1979; A. Arango and Dale Van Vleck, 2002; Walker et al., 2015). Selection for mature cow weight and/or frame score could be effective for changing size, but would result in little change in carcass and meat traits with the exception of hot carcass weight (Nephawe et al., 2004). Increasing mature cow BW may increase the amount of salable protein reflected in carcass weights of slaughter cows and their progeny. However, in range-based production settings, the optimal cow size varies according to, a specific marketing end product, genetic potential, and the production environment (Mulliniks et al., 2015).

For a producer with a fixed amount of land and feed resources, cow size should be a reflection of the number of cows within the herd to match forage quantity with the nutrient requirements of the herd. If the steady incline in cow size remains unrecognized, and herd size is not changed according to cow size, sustainability of range-based production may be compromised (Doye and Lalman, 2011; Scasta et al., 2019). Selection for small cows may increase herd size to match forage availability, but little is known about the consequences of cows too small for their production environment.

Long et al. (1975) developed a model to simulate data in an economic analysis of cow size under pasture and drylot systems. An economic analysis was performed on small (430 kg), medium (500 kg), and large (600 kg) cow sizes in both production scenarios. In the pasture system, small cows were more profitable; however, in the drylot system large cows were more profitable. Profitably in the pasture based production scenario was driven by the ability to stock more cows in a fixed land base. In the drylot system, the feed expense associated with a larger number of small cows was high and the increased income from small cows was not enough to offset the additional feed expense; therefore, in the drylot system, large cows were more profitable.

Cow Size on Cow Performance

Nutrient requirements vary with age, breed, sex, body condition, environment, physiological stress, milking potential, and weight (Hersom, 2015). The nutrient requirements of beef cows can be categorized as maintenance, growth, gestation, and lactation (Laurenz et al., 1991). As cow size increases, visceral and organ mass also increase, both of which influence the amount of dietary nutrients required by the cow for maintenance. A 30% larger cow requires 22% more energy daily (NRC, 1996), and will consume 22 to 28% (on dry matter basis) more forage daily, which decreases cow carrying capacity of the ranch (Beck et al., 2016).

Larger cows may generate more salvage value from increased BW. However, large cows may not be able to produce enough extra kg of calf weaning BW to compensate for the lower number of cows that could be maintained within a fixed total amount of available feed and land resources (Olson et al., 1982). This is largely due to the fact larger cows require more nutrients than smaller cows. Lalman and Beck (2019) recently modelled this using the California Net Energy System and NASEM (2016). Model assumptions were based on 556 and 647 kg cows. Reproductive efficiency and average daily milk production were assumed to be equal between both cow sizes. Increasing cow BW by 90 kg resulted in a 10% increase in feed costs, and generated approximately $19.20 per cow per year increase in cow salvage value for larger cows. As feed prices increased in this scenario, additional revenue for larger BW calves at weaning would have to increase in order to offset the additional cost to feed larger cows. The additional revenue from additional calf weaning BW associated with larger calves from a 90 kg larger cow would not be enough to cover the cost of maintaining larger cows.

Reproduction is imperative to the economic success of cow-calf enterprises (Buttram and Willham, 1989). Buttram and Willham (1989) studied the effect of increasing cow size on the reproductive performance in first, second and third parity cows. This study indicated that calving success was greater in small-sized cows and heifers compared with large-sized cows and medium-sized cows being were intermediate (Buttram and Willham, 1989). For second parity cows, overall pregnancy rate was lowest in large cows, intermediate for medium cows and greatest in the small cow size.

Buttram and Willham, (1989) noted that larger, later-maturing cows, which need more feed and reach puberty at heavier weights, required an environment that allows them to reach their genetic potential for growth. However, Marshal et al. (1984) conducted a regression analysis and reported that earlier-maturing cows tend to have reduced years in the herd, wean a lower number of calves, wean less kilograms, and produce less total beef. However, mature cow BW was quadratically related to years in the herd, the number of calves weaned and total calf weaning weight (Marshall et al., 1984). Marshal et al. (1984) suggested the optimal mature cow BW ranged from 600 to 628 kg to maximize maternal performance. Stewart and Martin (1983) conducted a regression analysis on Angus cows and suggested the optimal mature BW for maternal performance was between 465 and 493 kg. The suggested cow BW was based on years in the herd, number of calves produced, total calf BW weaned, average weight of calves weaned and calf BW weaned per year. However, environmental influences were not accounted for and management was typical of mid-west beef production were cows were dryloted in the winter. Optimal cow size may vary depending on the production environment and management practices. Similar to Marshal et al. (1982), Stewart and Martin (1983) found a quadratic relationship with mature BW of Angus cows and the total number of calves produced, total calf weight weaned, and the average BW of calves weaned. Stewart and Martin (1981) reported the number of calves produced decreased by -0.007 calves per kg of additional cow mature weight.

Vargas et al. (1999) studied the effects of frame size of first- second- and third or greater parity Brahman cows. Hip height measurement was used to assign frame size to heifers at 18-mo-old. Heifers were exposed to bulls at approximately 24 mo of age for a 120-d breeding season. Age at puberty was decreased in small- and medium-framed heifers compared with large-farmed heifers. Frame size did not influence calving rate percent in first-parity dams. In second-parity dams, small- and medium-framed cows had increased calving rate percentage compared with large-framed cows. Third or greater parity dams, with a small-frame had improved calving rate percent compared with medium- and large-framed cow. Overall, Vargas et al. (1999) indicated that smaller-framed Brahman cows achieve puberty more quickly prior to breeding at 24 mo of age and have improved female fertility.

Cow Size on Progeny Performance

Williams et al., (2018) evaluated the effect of cow size on calf 205-d weaning weights over two years. In the first year of the study, cow BW did not influence calf weaning weight. Although cow weight was confounded by age, in year two of the study, larger BW cows weaned 23.1 kg larger BW calves. Beck et al. (2016) studied the effect of stocking rate and cow BW on calf performance. Calf weaning BW increased 19 kg for each additional 100 kg increase in cow BW using Angus bulls for a 60-d breeding season. Even though calf BW at weaning was greater for larger cows, calf BW at weaning relative to cow BW at weaning decreased as cow BW increased (Beck et al., 2016). In contrast, Urick et al. (1971) reported a nonsignificant relationship of 1.93 kg increase in calf weaning weight for an additional 45.5 kg of cow BW. Stewart and Martin (1981) reported that calf BW at weaning increased 0.132 kg for each additional kg of cow BW. Vaz et al. (2016) reported no difference in calf BW at weaning between light (291 kg) and heavy (336 kg) cows; however, smaller cows had improved weaning BW relative to cow BW. Marshall et al., (1984) found a positive linear relationship of mature cow BW and average weaning BW of calves suggesting increasing cow BW increased calf weaning weights. Benyshek and Marlowe (1973) also reported a positive linear relationship between increasing cow BW and calf average daily gain and 205-d weaning

BW in Hereford cows. Increasing calf weaning weights could increase economic returns, the cost associated with feeding larger cows should be taken into consideration.

Olson et al., (1982) stratified cows into small, medium, large and very large cows based on cow BW after the breeding season. Cows were bred using artificial insemination (AI) over a period of 45-d followed by a 30-d natural service breeding period on pasture. The same bull was used for AI and clean-up bulls were the AI sire or a son of the AI sire. After weaning, steer calves were backgounded for approximately 82 d, then assigned randomly to individual pens for a 154-d post weaning test. Cow BW influenced the initial steer backgrounding BW with large dams producing the heaviest steers, medium and very large dams being intermediate, and small dams producing steer with the lowest BW. Dam BW did not influence steer final BW and average daily gain during the backgrounding phase. During the finishing phase, steer final BW was greatest in steers from large BW dams, lowest in steers from small BW dams, and medium and very large cows having progeny with intermediate final BW. Similar to the background phase, steer average daily gain was not influenced by dam BW during the finishing phase. In addition, dam size influenced steer progeny ribeye area with small cows producing steers with larger ribeye area compared with very large cows. Percent cutability and weight of trimmed retail cuts were greatest in steers from large cows, intermediate for steers from medium and small cows, and least in very large cows. Furthermore, yield grade was greatest in steers from very large cows (3.19), intermediate in small (2.75) and medium (2.79) cows and steers from large dams had the lowest yield grade scores (2.63). These authors concluded that when feed resources are not restricted, optimum cow size was in the 517 to 567 kg range considering efficiency of progeny through the finishing phase (Olson et al., 1982).

Vargas et al. (1999) reported large-framed cows had the largest calf BW at birth with calves from medium-framed cows being intermediate and lowest BW calves from small-framed cows. The authors suggest progeny from small-framed cows have reduced growth potential and possibly inadequate carcass weight and should be considered in determining the optimal cow size for a given production environment.

Increased selection of output traits through sire selection can also cause increase in mature cow size and progeny performance differences. Calf performance can be influenced by growth potential of sires within the same breed or between breeds (Grings et al., 1996). Colburn et al. (1997) reported differences in calf birth weights (33 and 36.1 kg) between low and high expected progeny difference (EPD) sires for birth weight respectively. Mahrt et al (1990) selected Polled Hereford sires with high and low yearling weight EPD and mated them with Angus cows. Calves born form the high yearling weight sire were 2.2 kg heavier at birth, 7.5 kg heavier at weaning, and 16.4 kg heavier as yearlings compared with the low yearling weight EPD sire. Using bulls with increased growth potential for weaning and yearling weights is correlated with mature size. Therefore, retaining replacement females with high growth potential would increase mature beef cow size of the herd (Lalman et al., 2019).

SUPPLEMENTATION DELIVERY STRATEGIES

The objective of supplement strategies is to supply nutrients that are deficient in the basal diet and either improve or maintain animal performance. However, the efficacy of supplement programs is influenced by the ability to reduce intake variation and meet the target supplement consumption amount (Bowman and Sowell, 1997). Variation in supplement intake may result in animals consuming over the targeted amount or animals not consuming supplement at all. Social dominance can add to the variation of supplement intakes. Older cows have been reported to force younger animals away from the feeding area, which creates increased variation in supplement intake across individual animals (Wagnon, 1965). Additionally, frequency of supplement delivery and amount impacts the amount of variation in intakes. Supplements that can be offered to animals infrequently in larger quantities can reduce the amount of labor required to deliver supplements (Bohnert et al., 2002; Schauer et al., 2005; Loy et al., 2007) and reduce variation in intakes. Reuter and Moffet (2016) suggested that innovations in automated feed delivery systems could reduce labor and improve animal welfare. Therefore, strategies that reduce variation in supplement intake and reduce the amount of labor required to provide supplements while maintaining or enhancing performance, have the ability to improve production efficiency.

Self-fed supplements provided to livestock are typically in the form of blocks, loose mineral, or liquid and require minimal labor. Hand-fed or dry supplements are supplied to livestock in the form of meals, cakes, cubes or pellets, which are often delivered to livestock more frequently then self-fed. In a review, Bowman and Sowell (1997) illustrated that the percentage of cattle and sheep that did not consume block supplements, dry supplements and liquid supplements was 14.3%, 15% and 23.5%; respectively. Additionally, the coefficient of variation of individual supplement consumption average was 79%, 41% and 60% for blocks, dry, and liquid supplements; respectively. When comparing studies that made direct comparison between hand-fed and self-fed supplements, 5% of animals were considered non-feeders for hand-fed supplements and 19% non-feeders were reported for self-fed supplements.

When comparing the costs associated with supplementation frequency, Sawyer and Mathis (2001) reported the weekly cost associated with daily, 3x per week, 1x per week, and self-fed to be $201.60, $86.40, $53.10, $48.60 respectively. Costs associated with supplement delivery included vehicle cost, costs associated with checking cows, and labor cost. Vehicle costs were estimated at $0.36/mile assuming a 30-mile round-trip. Costs associated with checking cows were assumed based on checking cows twice weekly. Labor costs were assumed at $9.00 per hour including one hour of driving and one hour of feeding the supplement. The more frequently the supplement needs to be provided to livestock increases the amount of labor and vehicle costs to deliver the supplement. Although self-fed supplements don’t require the extensive amount of labor required to supplement cattle daily, some additional labor costs are associated with self-fed supplements to monitor livestock. However, costs associated with self-fed supplements are less expensive then frequently fed supplements (Sawyer and Mathis, 2001), unless overconsumption of the self-fed supplement is high.

Schauer et al. (2005) studied the influence of protein supplementation frequency using pregnant cows to evaluate variation in supplement intake. Supplement treatments were fed daily or every 6 d. Supplements were fed in a trough 10 minutes after an audio cue. The percentage of cows in each treatment showing up on supplement days were not different between the two treatments (66 vs 70 % for daily and every 6 d, respectively). Change in cow body weight (BW) and body condition score (BCS) were not influenced by frequency of delivery. Additionally, the coefficient of variation for supplement intake and estimated supplement intake per cow was not influenced by supplementation frequency. These results are in contrast to several other studies in cattle and sheep that reported animals supplemented infrequently showed less variation in supplement intake than livestock supplemented daily (Foot and Russel, 1973; Kahn, 1994; Huston et al., 1999). Any differences in variation of supplement consumption may be due to larger quantities of supplement provided per animal when infrequent supplementation is implemented (Bowman and Sowell, 1997).

In an electronic feeder pilot study, Reuter et al. (2017) utilized 15 steers to evaluate variation in daily intake of a salt-limited self-fed supplement using a SmartFeed system (C-Lock Inc., Rapid City, SD). The coefficient of variation among steers was 69% over a 14-d data collection period. The coefficient of variation of daily intake of individual steers was 95%. This study illustrates the large variation in intakes that can occur with self-fed supplement.

Variation in supplement intake while grazing dormant range pastures may have negative impacts on cow performance due to inadequate supplement intake. Wyffels et al. (2019) supplemented cows on dormant range pastures with a canola meal-based pelleted supplement and reported cows with greater coefficient of variation in supplement intake had a negative association with cow BW change and distance traveled per day. Wyffels et al. (2019) suggested cows with greater variation in supplement intake would lose more

BW and travel less distance per day when grazing dormant rangelands. This may be indicative of cattle not consuming enough forage through grazing or supplement intake to satisfy their requirements.

Electronic feeders have the ability to track the number of visits per day cattle use the feeder. The number of visits per day reported by Wyffels et al. (2018) ranged from 3 to 7.7 in cows ranging from 1- to 6-yr old. Whereas, Reuter et al. (2017) reported yearling steers visiting an electronic feeder 5.4 times per day. Williams et al. (2018b) reported daily visits to an electronic feeder ranged from 1.9 to 6.3 for cows that had a minimum of 3 calf crops. Williams et al. (2018a) reported the number of visit cows made to an electronic feeder was 29.8 to 35.1 times per day while contained in a drylot. Differences in the number of visits to electronic feeders could be attributed to pasture size, animal age differences, and previous exposure to the feeder. In a production setting, the ability to know if cattle are visiting and consuming feed from electronic feeders may be beneficial to monitor herd health and performance.

The time of day cattle visit electronic feeders also varies across studies. Reuter et al. (2017) reported yearling steers visited the feeder most frequently at 1000 h. Whereas, Williams et al. (2018a) reported Angus-based beef cows ranging from 7- to 9-yr-old most frequently visited the feeder between the hours of 1700 to 2000 h, but the single hour with the most visits was between 0800 to 0900. Williams et al. (2018b) reported Angus-based beef cows ranging from 5.6 to 7.7 years old visited an electronic feeder most frequently during late morning (0900 to1200 h). Williams et al., 2018a suggest that the hour beef cows most frequently visit electronic feeders could be influenced by a stimulus such as feeders being filled.

Supplement frequency can influence grazing behavior. Schauer et al. (2005) reported that dams supplemented either daily or every 6 d with a protein supplement spent less time grazing than cows that did not receive protein supplement. The amount of time spent grazing was not different whether dams were supplemented daily or every 6 d. Distance traveled (m/d), distribution (measured as percentage of ha occupied·pasture^{-1}·yr^{-1}) and maximum distance from water (m/d) was not influenced by protein supplementation (Schauer et al., 2005).

Stephenson et al. (2017) studied the influence of low-stress herding and supplement placement to target cattle to specific grazing locations. Self-fed protein supplements were placed in areas to force grazing in areas that would otherwise be underutilized. Cows were herded to the supplement sites every other day at approximately 1100 to 1300 h. GPS collars were placed on cows to record the amount of time cows spent within 250-m of the supplement locations and the average distances cattle spent away from water. The amount of time cows spent within 250-m of the supplement was related to intake. When intake of the supplement was within recommended levels, cows spent 8.8 hr/d within 250-m of the supplement. Additionally, the time spent within 250-m of the supplement was an effective predictor of the percent of standing crop reduction of the target areas. The daily distance cows traveled from water sources was not influenced by treatment. These results indicate that supplement placement and herding is an effective management strategy to achieve targeted grazing.

Wyffels et al. (2018) examined the impact of cow age, ranging from 1- to 6-yr-old, and environmental conditions on individual supplement intake and behavior of cattle grazing rangelands during the winter. Supplement was provided free choice to cows using a SmartFeedPro feeder (C-Lock Inc. Rapid City, SD) to measure individual supplement intake (kg), number of visits per day, visit length (min/d), and intake rate (g/min). Daily supplement intake linearly decreased as cow age increased in year 1, but only a tendency was reported in year 2 for the relationship between intake and cow age. Cow age had a quadratic influence on the number of visits to the supplement per day in year 1, but a linear effect was reported in year 2 with 1 yr-old cows visiting the supplement more frequently than 6 yr-old cows. Amount of time spent consuming the supplement and intake rate linearly decreased as cow age increased in both years of the study. Furthermore, ambient temperature was shown to alter daily supplement intake by differing age groups. Young cows increased supplement intake, whereas older cows decreased supplement intake as ambient temperature decreased, which may be due to greater energetic needs for young cows to maintain homeothermy.

Wyffels et al. (2019) evaluated the repeatability of bred cows on supplement intake behavior across multiple years and the relationships between supplement intake behavior, performance, and grazing behavior. Supplement intake behavior was measured by average supplement intake (kg/d), supplement consumption rate (g/min), coefficient of variation (%) and the time spent at the feeder (min/d). Cows had free choice access to protein supplement using SmartFeedPro feeding systems (C-Lock, Inc. Rapid City, SD). Time spent grazing and distance traveled were monitored on a sub-set of 30 cows that were fitted with Lotek GPS collars (3300LR; Lotek Engineering, Newmarket, Ontario, Canada). Average daily supplement intake, supplement consumption rate (g/min), the coefficient of variation of supplement intake and the amount of time spent at the feeder were positively correlated across years. These results suggest individual animal intake behavior may be repeatable across years for bred cows grazing dormant season rangelands. Animal performance and grazing behavior were not correlated with intake or time spent at the feeder. However, a weak positive association between supplement consumption rate and change in body condition was reported suggesting consumption of supplement per minute may positively influence BCS.

SUMMARY OF RESEARCH

Previous studies evaluating the impact of cow size on progeny performance have been limited in the number of years the studies were replicated, data were simulated, or end at weaning. Previous research has demonstrated the impact of annual precipitation patterns and the impact on calf weaning weights relative to cow size (Scasta et al., 2015). The impact of cow size on performance studied over multiple years could eliminate variability in annual differences observed in previous studies. In addition, evaluating cow size using a systems approach would provide an understanding of the impact of cow size in all segments of the beef industry.

New innovative technologies in feed delivery systems have the ability to potently reduce the amount of labor required to supplement pasture cattle and therefore may reduce input costs. Electronic feeders with the ability to reduce supplement intake variation should be investigated to increase the efficiency of supplementation strategies by achieving targeted supplement amounts. Previous research quantifying the number of cows that utilized electronic feeders, and the accuracy of feed dispensed have not previously been reported and is a focus area of this thesis.

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CHAPTER II: The influence of cow size on performance and steer progeny performance

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ABSTRACT

Production efficiency requires an understanding and managing for genetic potential. Genetic potential should be evaluated within a given production system and environmental constraints. The objectives of this retrospective analysis were to determine the influence of cow body weight (BW) adjusted to a common body condition score (BCS) of 5 at weaning, on cow-calf performance and steer progeny performance from birth to harvest. Data were collected at the Gudmundsen Sandhills Laboratory near Whitman, NE on crossbred mature cows (n = 1715) from 2005 to 2017. Cow BCS at calving, pre-breeding, and weaning were positively associated ($P < 0.01$) with greater cow BW. Increasing cow BW was positively associated ($P < 0.01$) with the percent of cows that conceived during a 45-d breeding season. For each additional 100-kg of cow BW, steer BW increased ($P < 0.01$) at birth (2.50 kg) and adjusted 205-d weaning BW (8.98 kg). Steer initial feedlot BW ($P \leq 0.01$; 7.20 kg), reimplant BW (10.47 kg), and final BW (10.29 kg) increased for each additional 100-kg of cow BW. However, steer overall ADG in the feedlot and the number of days on feed was not influenced ($P \geq 0.67$) by cow BW. Marbling scores, backfat thickness, longissimus muscle area, and yield grade were not affected ($P \geq 0.07$) by cow BW. Hot carcass weights of steers were positively influenced (6.48 kg; $P = 0.01$) with each additional 100-kg of cow BW. Utilizing regression equations to predict performance, total output (calf weaning and cull cow BW) was increased 4,960 kg utilizing a 454 kg cow compared with a 554 kg cow given fixed land resources. These data suggest larger cows within the herd and production system of the current study may have increased reproductive performance and

offspring performance; however, total production output may be increased in smaller-sized cows.

Key words: cow performance, cow size, production efficiency, steer progeny performance

INTRODUCTION

In efforts to increase income, cow-calf producers have placed more selection pressure on growth traits to increase weaning weights (Lalman et al., 2019). Cow-calf producers that retain replacement females with superior growth genetics may increase the mature cow size of the herd. Dramatic differences can be made in cow size by genetic selection, as growth traits are highly heritable (Gosey, 2003). Previous work has shown increasing cow body weight (BW) is negatively correlated with the number of calves weaned (Stewart and Martin, 1981). Scasta et al. (2015) illustrated annual precipitation in semiarid environments alters the response cow size on calf BW at weaning with larger cows weaning heavier calves in drought years and smaller cows weaning the heaviest calves in years with exceptional rainfall. Increased cow size increases forage intake, which decreases the number of animals that can be maintained in a fixed land base (Beck et al., 2016). In addition, Doye and Lalman (2011) estimated increasing cow size 45 kg increases feed cost by approximately $42 to support the added forage intake associated with larger cows. Smaller-framed cows may produce greater herd total kilograms weaned and increase gross revenue due to increased stocking rates on fixed resources (Scasta et al., 2015; Bir et al., 2018).

Previous research has focused at the influence of cow size on calf weaning weights (Scasta et al., 2015; Beck et al., 2016), but these studies are limited in length of time and size, or simulated (Notter et al., 1979; Bir et al., 2018). Research has focused on moderating cow size, but research pertaining to the impact of cow size using a systems approach is limited. We hypothesized that increased cow size in a semi-arid environment could be detrimental to reproductive performance, but steer progeny may have increased pre- and post-weaning performance. Therefore, the objective of this research was to determine the impact of mature cow size on cow-calf performance and post-weaning steer progeny performance using a systems approach.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee at the University of Nebraska-Lincoln (IACUC approval number 1474) approved animal procedures and facilities used in this experiment.

Site Description

Warm season grasses dominate upland range pastures at the University of Nebraska, Gudmundsen Sandhills Laboratory (GSL), near Whitman, NE. The primary plants on range pastures include little bluestem [*Andropogon scoparius* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon halli* Hack.), switchgrass (*Panicum virgatum* L.), sand lovegrass [*Eragrostis trichoides* (Nutt.) Wood], and blue grama [*Bouteoua gradis* (H.K.B.) Ex Griffiths]. Subirrigated meadows at GSL are dominated by cool season grasses including slender wheatgrass [*Elymus trachycaulus* (Link) Matte], redtop bent (*Agrostis stolenifera* L.), timothy (*Phleum pretense* L.), Kentucky bluegrass (*Poa pratensis* L.), and smooth bromegrass (*Bromus inermus* Leyss.) (Griffin et al., 2012). Average annual precipitation at GSL during the duration of the data collected was 54.09 cm with a standard deviation of 16.60

cm. Upland, native range pastures at GSL are stocked at 0.6 animal unit months, whereas sub-irrigated meadows are stocked at 3.0 animal unit months.

Cow management

Cow-calf data were collected from 2005 through 2017 at GSL. Cow performance data were obtained from both March- and May-calving herds at GSL to determine the impact of cow size on cow performance and steer progeny performance from birth to slaughter. Cows in this study (n = 1715) were Husker Red (~ 5/8 Red Angus, 3/8 Simmental) ranging from 5- to 11-yr-old. Age criteria included cows that were at least 5-yr-old or older to ensure only mature cows were evaluated. Cow body weights (BW) and body condition score (BCS; 1 = emaciated, 9 = obese; Wagner et al., 1988) were collected at pre-calving, pre-breeding and at weaning. To correct for differences in BCS at weaning, cow BW at weaning was adjusted to a common body condition score of 5.

Over the years of this retrospective study, breeding management differed in terms of synchronization protocols and bull to cow ratios. Bulls used for breeding were Husker Red (~5/8 Red Angus, 3/8 Simmental) with moderate growth potential. The same bulls were used in both the March and May-calving herds within a year. In all years, March-calving cows were exposed to fertile bulls starting in June of each year for a 45-d breeding season. In yr 2008 to 2013 and 2015 to 2017, a subset of cows were artificially inseminated (AI) and exposed to clean-up bulls for a 45-d breeding season. Bulls selected for AI were also selected for moderate growth potential. The average bull to cow ratio following AI was 1 bull to 26 cows. In 2008, cows allotted to AI were synchronized using a 7-d Co-Synch with a controlled internal drug release (CIDR; EAZI-BREED CIDR; Zoetis Animal Health, Parsippany, NJ). Briefly, on d -10 cows received a 2-mL i.m. injection of gonadotropin releasing hormone (GnRH; Factrel; 100µg gonadorelin hydrochloride; Zoetis Animal Health, Parsippany, NJ). Cows also received a CIDR on d -10. On day -3 CIDRs were removed and 5 mL of prostaglandin $F_{2\alpha}$ was given i.m. (Lutalyse, Zoetis, Parisippany, NJ). On d 0 a second shot of GnRH was given and cows were inseminated. In 2009-2013, AI cows were synchronized using two shots of prostaglandin $F_{2\alpha}$ (Lutalyse, Zoetis, Parisippany, NJ) 14-d apart. Heat detection patches (Estrotect; Rockway Inc., Spring Valley, WI) were placed on cows when the second shot of prostaglandin $F_{2\alpha}$ was administered. In 2015 to 2017, AI cows were synchronized using the 7-d Co-Synch protocol outlined above. In non-AI cows each year, cows were estrous synchronized with a single injection of $PGF_{2\alpha}$ (25 mg; Lutelyse; Zoetis Inc., Parisippany, NJ) after a 5-d exposure to fertile bulls (bull-to-cow ratio of 1:17). The May-calving herd was initiated in 2009. Each year, cows were exposed to fertile bulls in August for a 45-d breeding season. In 2009 and 2010, all May calving cows were bred using AI using a 7-d CO-Sync protocol as described above. In years 2011 to 2017, estrous was synchronized in the May cowherd with a single injection of $PGF_{2\alpha}$ (25 mg; Lutelyse; Zoetis Inc., Parisippany, NJ) after a 5-d exposure to fertile bulls (bull-to-cow ratio of 1:17). Each year, pregnancy diagnosis was determined at weaning by transrectal ultrasonography.

Steer pre-weaning management

At birth, bull calves received a 7-way clostridial vaccine (Alpha 7, Boehringer/Ingelheim, Duluth, GA). Bull calves were castrated at branding and received vaccinations for infectious bovine rhinotracheitis, bovine viral diarrhea types I and II, bovine parainfluenza virus-3, bovine respiratory syncytial virus, Mannheimia haemolytica, and Pasteurella multocida (Vista Once SQ, Merck, Kenilworth, NJ). A 7-way clostridial vaccine was also given at branding (Vision 7, Merck, Kenilworth, NJ). At weaning, steer calves received one vaccination of Vista Once SQ and received a second dose 14 d later. A 7-way clostridial vaccine with somnus (Vision 7 Somnus, Merck, Kenilworth, NJ) was also given at weaning. Steer BW was collected at birth, pre-breeding and at weaning each year. An adjusted 205-d weight was calculated without adjustments for cow age or sex of calf. March-born calves were weaned in September through December depending on forage availability. May-born calves were weaned in December or January each year.

Post-weaning steer data

After weaning, March-born steers remained at GSL for 2 wk with *ad libitum* access to hay. Steers were then transported to the West Central Research and Extension Center (WCREC) and entered the feedlot. Over 54 d, steers were adapted to a common finishing diet of 48% dry-rolled corn, 7% prairie hay, 40% wet corn gluten feed and 5% supplement (dry matter basis). Steers were implanted with 100 mg of trenbolone acetate and 14 mg estradiol benzoate (Synovex Choice; Ft. Dodge Animal Health, Overland, KS) upon feedlot entry. At approximately 100 d prior to harvest, steers received a second implant with 200 mg trenbolone acetate and 24 mg estradiol benzoate (Synovex Plus; Ft. Dodge Animal Health, Overland, KS).

After weaning, May-born steers grazed subirrrigated meadow with 0.45 kg/d supplement or received ad libitum hay with 1.8 kg/d supplement during the winter depending on the study. May-born steers received Revalor G (Merck Animal Health, Summit, NJ) and grazed upland range pastures at GSL, then entered the feedlot at

WCREC in mid-September. Upon feedlot entry in September, long-yearling steers were implanted with 36 mg zeranol (Ralgro; Merck Animal Health, Summit, NJ). Steer BW was collected approximately 97 d prior to slaughter and steers were re-implanted with Synovex Plus (Ft. Dodge Animal Health, Overland, KS). May-born steers were adapted over 28 d to the same finishing diet outlined above.

Upon feedlot entry, all steers were limit fed 5 d at 2.0% of BW and weighted 2 consecutive days. Feedlot entry BW was the average of these 2 time points. Re-implant BW was one weight collected on all steers prior to that days feeding. Final BW was calculated for March and May-born steers from hot carcass weight (HCW) adjusted to a common dressing percentage of 63%. Each year within the different season of calving, steers were sent as a single group to a commercial facility (Tyson Fresh Meats, Lexington, NE) when backfat (BF) thickness was estimated to be 1.27 cm using visual appraisal. Carcass data were collected after a 24-hr chill period and included, HCW, BF, marbling, yield grade (YG), and longissimus muscle area (LMA).

Measure of efficiency

We assumed 809 hectares in the Nebraska Sandhills providing 0.5 AUM/acre. Small cow-calf pairs were considered 1.3 AUE and large cow-calf pairs were considered 1.5 AUE. Grazing was assumed for 5 months. Calf crop was estimated at 50% steers and 50% heifers. A 15% heifer replacement rate was assumed to maintain herd size resulting in 54 and 46 heifers sold at weaning for small and large cows, respectively.

Statistical Analysis

All analyses were performed using SAS 9.4 PROC GLIMMIX (SAS, Cary, NC). A similar initial model was used to analyze both the cow and steer data. To account for differences in both season of calving (March or May) and differences among years, a SEASONYR term was determined. The initial model included the fixed effects of linear adjusted cow BW at weaning, linear calf birth weight, and linear calf Julian birth date and the random effects of adjusted cow BW by SEASONYR, linear calf birth weight by SEASONYR, and calf birth date by SEASONYR and residual error. Adjusted cow BW, calf birth weight, and calf birth date terms were tested over the random interaction effect with SEASONYR. Non-significant calf birth weight and birth date terms ($P > 0.05$) were dropped to produce the final model. A Normal distribution was assumed for all measures, except for cow pregnancy rate, where a binomial distribution was assumed. Pregnancy data was evaluated using the odds and odds ratio. Odds (*0*) are the (*P*) of being pregnant over not being pregnant (1-*p*). Significance was determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

Cow performance

Table 2.1 shows the average demographics of cows that were included in the retrospective analysis. The average adjusted cow BW over the 13-yr period was 501± 2 kg and ranging from 357 to 645 kg. Olson et al. (2011) estimated the average cow BW of popular U.S. beef breeds to be 630 kg in 2009. Meaning average cow BW in the current study is 129 kg less than the national average was in 2009. Based on data from the National Agriculture Statistics Service, dressed slaughter cow weights have increased 16 kg since 2009. It is likely that the national mature cow size has increased since 2009. This study has cows that are relatively small compared to the 2009 estimate and are most likely much smaller than the current national average cow size.

Cow BCS at calving, breeding, and weaning were positively associated (*P* < 0.01; Table 2.2) with increasing cow BW. The positive relationship with increasing cow BW on BCS at parturition and calving may be influenced by the ability of larger cows to consume more forage. In support of this, the change in BW from pre-calving to weaning was positively related to increasing cow BW 100-kg (21.2 kg; *P* < 0.01). Dry matter intake per cow increases 0.0185 kg for each liter increase in rumen capacity under low-quality forage conditions (Nutt et al., 1980).

The following assumptions were used to evaluate increasing cow size on forage intake; 5-yr-old cow, not pregnant, consuming range pastures in June. Estimates were calculated using a 454 kg cow and a 554 kg cow. The larger cow size was estimated to produce an additional 0.26 kg/d of milk compared with the smaller cow size based off estimates by Walker et al. (2015). Using the NASEM (2016) to estimate intakes, the 554 kg cow would require an additional 1.54 kg of forage daily and 562 kg additional forage annually. Similar values were reported by Wiseman et al. (2018) where an additional 600 kg of forage was required for an additional 100-kg of cow BW.

Pregnancy rates in the current study were positively influenced (*P* < 0.01; Table 2.2) with increasing cow BW. Cow pregnancy rates increased 3% as cow BW increased 100-kg (Table 2.6). This could be attributed to the inability for small cows to maintain BW from pre-calving to weaning. Cow BW loss after calving is indicative of the utilization of energy stores to compensate for dietary deficiencies (Mulliniks et al., 2016). Spitzer et al. (1995) reported cows with high postpartum BW gain returned to estrus more quickly after parturition and had improved pregnancy rates. Larger cows in the data set that gained more BW during the growing season may have had the ability to gain BW more quickly after calving which positively influenced pregnancy rates. As mature BW increased in our data set, pre-calving BCS also increased. Greater BCS may have attributed to improved pregnancy rates as cow BW increased. In contrast to the current study, Beck et al. (2016) reported that cow BW did not influence the pregnancy rates of cows grazing improved pastures. Mulliniks et al. (2018) suggests in limited nutrient environments, breeds with greater growth and milk potential may have less energy partitioned to reproduction.

Cow size on steer pre-weaning performance

As adjusted cow BW increases by 100-kg, steer BW at birth increased by 2.50 kg ($P < 0.01$; Table 2.3). Similarly, Stewart and Martin (1981) reported an increase of 4.8 kg in calf BW at birth for every 100 kg increase in cow BW. Steer adjusted 205-d weight in the current study increased 8.98 kg ($P < 0.01$) for each 100-kg increase in cow BW. In a more humid environment, Beck et al. (2016) reported a 19 kg increase in calf BW at weaning for each 100-kg increase in cow BW. Similar to the current study, Bir et al. (2018) reported 100-kg increase in cow BW increased calf BW at weaning by 7.0 kg. Differences in steer weaning weights between these studies could be attributed to geographical locations having influence on pasture quality and quantity, environmental conditions, and breed differences. Although the impact of cow size on steer weaning weights may be more pronounced in more temperate climates with improved pastures (Beck et al., 2016). Scasta et al. (2015) reported that the drought gradient influences the cow size that weans the largest calf. These authors reported an 84 kg range in calf BW at weaning in calves from small-framed cows across 4-yrs with varying precipitation amounts. However, large-framed cows had only an 11 kg range in calf BW at weaning across the same variation in precipitation amounts. These results suggest that weaning weights of calves are less variable across the drought gradient when born from larger sized cows. Furthermore, this study suggests, as precipitation patterns change, the optimal sized cow for maximum weaning BW also changes (Scasta et al., 2015). Our data was collected over an 11 year period, so the variation in calf weaning weights due to environmental factors by year is likely reduced.

The ratio of calf weaning weight relative to unadjusted cow BW at weaning decreased -0.009 kg ($P < 0.01$; Table 2.3) as cow BW increased 100-kg. Similarly, smaller cows demonstrate greater percentage weaned per BW compared with larger cows in an environment with an average precipitation of 34.4 cm (Scasta et al., 2015). In the current study, average precipitation was 54.09 cm which may increase the weaning weights of progeny from smaller dams thereby influencing weaning weight ratios. Beck et al. (2016) reported that increasing cow BW by 100-kg decreased weaning efficiency (kg calf weaned per 100 kg cow BW) 6.7-kg per calf.

Cow size on steer progeny post-weaning performance

The regression coefficients related to steer feedlot performance are reported in table 2.4. Steer feedlot entry BW, BW at reimplant, and final live BW increased ($P \leq 0.04$) for each 100-kg increase of cow BW. However, feedlot ADG was not influenced ($P \geq 0.33$) by cow BW. In agreement, Olson et al. (1982) reported cow size influenced steer progeny BW at the start of the backgrounding phase and steer final live BW with no differences in ADG. Smith (1979) suggested that large, late maturing breeds gained more rapidly in the feedlot and were more efficient than small-framed cattle. Barber et al. (1981) suggested rate and efficiency of gain in the feedlot in addition to carcass characteristics are major determinants of profit or loss in beef production. Depending on input costs and market prices for finished cattle, steer progeny from larger cows may be more desirable in the feedlot due to greater initial and final live BW. Lancaster et al. (2014) conducted a meta-analysis on 29 experiments and reported initial finishing BW of steers after backgrounding had a significant positive relationship with HCW ($r^2 = 0.939$). Therefore, steers with greater feedlot entry BW translates to greater HCW. However, when retaining ownership of steers produced by smaller dams in the current study resulted in more total HCW compared with steers produced from larger dams. This was due to the fact that more steers were produced because more cow-calf pairs could be maintained (Table 2.6).

Regression coefficients used to estimate the influence of cow BW on carcass performance of steer progeny is reported in table 2.5. Steer HCW increased 6.48 kg ($P = 0.01$) for each additional 100-kg increase of cow BW. Olson et al. (1982) reported increasing HCW of steers adjusted to the same slaughter age with similar 12th rib fat thickness from small- to large-sized cows, but very large cows did not produce the most steer HCW. Nephawe et al. (2004) reported that the genetic correlation between cow weight and the HCW of steers to be (0.81) suggesting cow size is highly correlated with steer HCW. Our results support the notion HCW of steers is increased by increasing cow BW. Considering the discounts received for small carcasses compared to discounts for carcasses too heavy, selection pressure should favor larger cow BW if heavier carcasses are more desirable (Nephawe et al., 2004). Carcasses between 181 and 227 kg are subject to heavy discounts (USDA-Market News Service, 2020). However, smaller cows in the current study did not produce steers with HCW subject to discount for being too small.

Marbling score in the current study tended (P = 0.07) to increase 0.14 for each 100-kg increase in cow BW. The positive relationship between cow BW and steer marbling scores reported in our study contrasts with other findings. Olson et al. (1982) reported similar marbling scores of steers from different size cows. Nephawe et al. (2004) reported the genetic correlation between mature cow weight and marbling scores of steer progeny to be negative, and suggested selection for smaller cows would slowly increase marbling in steers. The inverse relationship between mature cow size and steer progeny marbling scores suggests reducing mature cow size would increase marbling scores of progeny. Backfat, yield grade, and longissimus muscle area (LMA) were not influenced ($P \geq 0.47$) by cow size in this study. The genetic correlation between mature cow BW and the LMA of steer progeny was reported to be low to moderate (Nephawe et al., 2004), which may explain why cow BW did not influence steer LMA in the current study. It is important to note that cattle in the current study were slaughtered when BF thickness was estimated at 1.27 cm and the cattle in Nephawe's study where slaughtered at a constant age, which may lead to discrepancies in the data between the two studies. However, in agreement with Nephawe et al. (2004), these data suggest steer HCW may increase as cow BW increases, but differences in carcass quality may not be influenced by mature cow BW. Camfield et al. (1999) reported increased HCW and LMA in large-framed, late maturing steers in both feedlot-developed steers and pasture-developed steers, but decreased quality grade scores compared with intermediate- and small-framed steers. It is likely large framed steers would require additional days on feed to improve quality grade scores which may increase input costs to feed large framed steers longer.

Cow size and efficiency

Estimating total output was based on the regression coefficient estimates in a hypothetical scenario assuming small cow size (454 kg) and large cows (554 kg; Table 2.6). A total of 154 and 132 head of cow-calf pairs could be maintained in the assumed fixed pasture space for 5 mo for small and large cows, respectively. Steer weaning weights were estimated using the regression coefficients at 220 kg and 229 kg for small and large dams respectively. Heifer weaning weights were 181 and 185 kg for small and large dams respectively. Cow pregnancy rates were 94% and 97% for small and large cows; respectively. Due to the pregnancy rate differences and heifer replacement rate, the number of cull cows sold each year was 9 and 4 cows for small and large cow herds. When taking into account the offspring BW and cull cow BW, total output at weaning was 4,960 kg greater in the small-sized cow herds compared to large-sized cow herd. If calves were retained post-weaning through the finishing phrase (Table 2.6), the number of steers produced in the small cow sized herd produced an additional 4,345 kg of steer HCW compared with to the large cow size. The increase in kilograms produced at weaning and after the feedlot phrase is driven by increased stocking rate in smaller-sized cows.

A hypothetical partial budget was constructed to evaluate increasing cow size by 100-kg in two 100 head cow herds (Table 2.7). Calf prices were estimated using an average price for 204 to 249 kg steer and heifer prices over a 10 yr period from combined auctions in Nebraska ($3.97/kg; LMIC, 2019). Pasture lease rates were an average of 5 yr obtained from the University of Nebraska Farm Real Estate Market Survey for pasture lease rates in the North region on average quality pastures ($38.55 per cow-calf pair; Nebraska Farm Real Estate Reports). Winter grazing was based off pasture lease fees for low third-quality pasture in the North region of Nebraska (Nebraska Farm Real Estate Reports). In the small cow scenario, 2,354 acres would be need to support cows, replacement heifers, and bulls using recommended stocking rates in the Nebraska Sandhills for the winter. For the large cow scenario, 2,436 acres would be required to maintain the cows, replacement heifers, and bull using recommended stocking rates. Given these assumptions, the small cow size scenario generated a profit of $2,245 and the large cow scenario lost $7,528. Utilizing a smaller cow size was more economical even though larger cows produced greater salvage value, increased calf weaning weights, and had improved reproduction.

In conclusion, smaller cows generated more total output throughout the entire beef production system and generated more revenue at weaning. The duration of the current retrospective analysis likely reduced annual variation in relation to performance of cows and calves depending on year. Overall, smaller cows in this study have reduced pregnancy rates and produce smaller steer calves compared with larger cows. Our data suggests that BCS and change in BW is improved in larger cows from parturition to weaning, which may lead to an increase in the number of pregnant cows. Larger cows weaned larger steer calves and produced heavier carcass weights at slaughter; however, offspring from small dams did not result in discounted carcass weights The tradeoff between cow sizes should be evaluated in the wide variety of production segments and environments within beef production to optimize efficiency.

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Table 2.1 Mean, standard deviation, and range of cow body weight (BW) and age

Measurement	Mean	SD	Minimum	Maximum
Cow BW, kg	501	49	357	645
Cow age, yr	6.5	1.5	5	11

Table 2.2 Regression coefficients used to evaluate increasing cow body weight 100 kg on cow performance

Measurement	Estimate	SEM	*P*-value
Body Weight, kg			
Pre-calving	89.7	1.87	<0.01
Pre-breeding	91.8	2.01	<0.01
Weaning	111.0	0.88	<0.01
BW change[1]	21.2	1.74	<0.01
BCS[2]			
Pre-calving	0.41	0.03	<0.01
Pre-breeding	0.42	0.03	<0.01
Weaning	0.35	0.03	<0.01
Pregnancy Rate	0.95	0.21	<0.01

[1]BW change pre-calving to weaning
[2]BCS = body condition score

Table 2.3 Regression coefficients used for estimating adjusted cow body weight at weaning on steer progeny pre-weaning performance

Measurement	Estimate[1]	SEM	*P*-value
Body Weight, kg			
Birth	2.50	0.33	<0.01
Adjusted 205-d	8.98	1.64	<0.01
WW ratio[2]	-0.09	0.003	<0.01
Average Daily Gain, kg/d			
Birth to weaning	0.04	0.008	<0.01

[1] Estimate = regression coefficient used to evaluate increasing cow body weight 100 kg on steer progeny

[2] Kilogram of calf weaned divided by unadjusted cow body weight at weaning

0

Table 2.4 Regression coefficients used for estimating the influence of 100-kg increase of cow body weight on steer progeny feedlot performance

Measurement	Estimate[1]	SEM	*P* - value
Body weight, kg			
Entry	7.20	3.12	0.04
Reimplant	10.47	3.51	0.01
Final live weight[2]	10.29	3.61	0.01
Average Daily Gain			
Beginning[3]	-0.07	0.07	0.33
Ending[4]	0.03	0.04	0.45
Total[5]	0.008	0.02	0.67
Days on Feed	0.65	1.26	0.61

[1] Estimate = regression coefficient used to evaluate increasing cow size on steer progeny
[2] Final live weight was calculated using hot carcass weight adjusted to a common dressing percentage of 63
[3] Beginning = average daily gain from feedlot entry to reimplant
[4] Ending = average daily gain from reimplant to slaughter
[5] Total = average daily gain throughout the feeding period

1

Table 2.5 Regression coefficients used to estimate the influence of increasing cow body weight 100-kg on steer progeny carcass performance

Measurement	Estimate	SEM	*P*-value
HCW, kg[1]	6.48	2.23	0.01
Marbling	0.14	0.07	0.07
Backfat, cm	-	0.0001	0.97
Yield Grade	0.0004	0.0005	0.47
LMA, cm sq[2]	0.0001	0.001	0.90

[1] HCW = additional hot carcass weight of steers attributed to 100 kg increase in cow BW
[2] LMA = Longissimus muscle area

Table 2.6 Efficiency measured by total output using small (454 kg) and large (554 kg) cows using recommended stocking rates in the Nebraska Sandhills

Measurement	Small	Large
Cow-calf pairs[1], hd.	154	132
Number of steers	77	66
Heifers sold at weaning	54	46
Pregnancy rate, %	94	97
Cull cows	9	4
Steer weaning weight, kg	220	229
Heifer weaning weight, kg	181	185
Total output[2], kg	30,800	25,840
Retaining ownership[3]		
Steer HCW, kg	437	444
Total output[4], kg	33,649	29,304

[1] Number of cow-calf pairs that can be maintained for 5 mo using recommended stocking rates for the Nebraska Sandhills

[2] Total output measured by the sum of the number of steers, heifers, and cull cows multiplied by their respective weights at weaning

[3] Retaining ownership of steer progeny through the feeding period

[4] Estimate of total output of steer hot carcass weights between small and large dams

Table 2.7 Partial budget analysis used to evaluate net revenue generated from small (454 kg) and large (554 kg) cows using recommended stocking rates in the Nebraska Sandhills

Measurement	Small	Large
Number of cow-calf pairs	154	132
Number of steers	77	66
Heifers sold at weaning[1]	54	46
Steer weaning weight, kg	220	228
Heifer weaning weight, kg	181	185
Weaned calf price[2], $/kg	3.97	3.97
Weaned calf value, $	106,054	93,525
Cull cow body weight, kg	454	554
Cull cow price, $/kg	1.23	1.23
Number of cull cows	9	4
Cull cow revenue, $	5,026	2,726
Number of bulls	6	5
Price of bulls, $	3,000	3,000
Pasture lease[3], $38.55/pair	29,684	25,443
Winter pasture[4], $/acre	26	26
Acres required for 7 mo.	2,352	2,436
Winter grazing cost, $	61,152	63,336
Profit, $	2,245	-7,528

[1] Number of heifers sold after retaining 15% for replacements
[2] Calf prices obtained using a 10 yr average for Nebraska combined auctions (LMIC, 2019)
[3] Pasture lease fees using an average of 5 years for the North region average quality pasture assuming 5 mo of grazing (Nebraska Farm Real Estate Reports)
[4] Winter pasture cost assuming low third-quality pasture in North region after weaning prior to spring turnout(Nebraska Farm Real Estate Reports)

CHAPTER III. The influence of dam size on heifer progeny performance in the Nebraska Sandhills

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ABSTRACT

Current research suggests small- to moderate-sized mature cows are more efficient economically and biologically possibly due to earlier maturation and longevity. However, the influence of dam size on heifer progeny reproductive performance in the Nebraska Sandhills is uncertain. The objective of this retrospective analysis was to determine the influence of dam body weight (BW) on heifer progeny pre- and post-weaning growth and reproductive performance. Data were collected from 2005 to 2017 at the Gudmundsen Sandhills Laboratory near Whitman, NE on crossbred mature dams (n = 851). A linear regression analysis of dam BW on heifer performance was performed using the GLIMMIX procedure of SAS (SAS, Cary, NC). As dam BW increased 100-kg, heifer progeny pre-weaning BW increased ($P < 0.01$) at birth (1.14 kg), weaning (2.38 kg), and adjusted 205-d weaning weight (4.39 kg). Heifer progeny BW also increased ($P < 0.01$) post-weaning (4.29 kg), at pre-breeding (4.99 kg), at pregnancy check (6.00 kg), and prior to calving (5.94 kg). Heifer progeny body condition score (BCS) at pregnancy diagnosis was increased (0.02 BCS; $P < 0.05$) for every additional 100-kg increase in dam BW; however, heifer progeny BCS prior to calving was not influenced ($P = 0.91$) by dam BW. The odds of a heifer achieving puberty prior to the breeding season, final pregnancy diagnosis, and calving within the first 21-d of the calving season was not influenced by increasing dam BW ($P \geq 0.11$). Results from this study indicate increased dam BW increases heifer progeny BW, but has minimal influence on heifer progeny reproductive performance given this production system.

Keywords: beef cows, dam size, heifer performance

INTRODUCTION

An increased selection pressure for beef cattle to have increased carcass weights has been reflected in the average mature cow size. For instance, dressed slaughter cow weight has increased 78 kg over the last 44 yr (USDA-NASS). The increase in mature cow size has been the result of increased selection for high growth rates in efforts to increase the weaning weights, yearling weights, and hot carcass weights of progeny, while simultaneously retaining replacement females (Johnson et al., 2010). Although growth traits do contribute to the profitability to cow-calf producers, reproduction has been shown to be 5 times greater in influencing ranch profitability compared to selecting for growth traits (Trenkle and Willham, 1977). Optimizing cow size with forage resources should be a priority not to exceed what the production environment can produce (Doye and Lalman, 2011) and should be considered when developing replacement females.

Patterson et al. (1992) suggested decisions in the selection and management of replacement beef heifers should focus on physiological processes that influence puberty. Age at puberty is critical when heifers are bred to calve at 2-yrs-old (Patterson et al., 1992). Buttram and Willham (1989) concluded smaller-framed cows, which mature at an earlier age and lighter BW, may be optimal for heifers when raised under less than optimal conditions. Additionally, breeds that have larger mature size reach puberty at a later age (Cundiff, 1986) and require an environment capable of supporting additional nutrient requirements associated with larger cows. Extensive research has focused on heifer selection; however, minimal research is available about the influence of mature dam size on heifer progeny performance. We hypothesized, as dam size increases, heifer progeny BW may increase and reproductive performance would decrease. Therefore, the objective of this retrospective study was to evaluate the influence of increasing dam BW on heifer progeny growth and reproductive performance.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee at the University of Nebraska-Lincoln (IACUC approval number 1474) approved animal procedures and facilities used in this experiment.

Study Site

Upland range pastures at the Gudmundsen Sandhills Laboratory (GSL) are dominated by warm season grasses. The primary plants on range pastures include little bluestem [*Andropogon scoparius* (Michx.) Nash], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], sand bluestem (*Andropogon halli* Hack.), switchgrass (*Panicum virgatum* L.), sand lovegrass [*Eragrostis trichoides* (Nutt.) Wood], and blue grama [*Bouteoua gradis* (H.K.B.) Ex Griffiths]. Subirrigated meadows at GSL are dominated by cool season grasses including slender wheatgrass [*Elymus trachycaulus* (Link) Matte], redtop bent (*Agrostis stolenifera* L.), timothy (*Phleum pretense* L.), Kentucky bluegrass (*Poa pratensis* L.), and smooth bromegrass (*Bromus inermus* Leyss.) (Griffin et al., 2012). Average annual precipitation at GSL during the duration of the data collected was 54.09 cm with a standard deviation of 16.60 cm. Upland range pastures at GSL are stocked at 0.6 animal unit months, whereas sub-irrigated meadows are stocked at 3 animal unit months.

Cow management

Cow-calf data were collected from 2005 through 2017. Performance data were collected on both March and May calving herds to determine the impact of dam size on heifer progeny post-weaning performance. Dams in this study (n = 851) were Husker Red (~5/8 Red Angus, 3/8 Simmental) and ranged from 5- to 11-yr-old. Dams less than 5-yr-old were omitted from the data set to eliminate the potential effects of immature dam size on heifer progeny performance. Dam body weight (BW) collected at weaning was adjusted to a common condition score of 5 (1 = emaciated, 9 = obese; Wagner et al., 1988) and used to evaluate the influence of dam size on heifer progeny. A complete description of dam management during this study is reported in Chapter II.

Pre-weaning heifer management

At birth, all heifer calves received a 7-way colstirdial vaccine (Alpha 7, Boehringer/Ingelheim, Duluth, GA). Vaccination for infectious bovine rhinotracheitis, bovine viral diarrhea types I and II, bovine parainfluenza virus-2, bovine respiratory syncytial virus, Mannheimia haemolytica, and Pasteurella multocida (Vista Once SQ, Merck, Kenilworth, NJ) was given at branding. A 7-way clostridial vaccine was also given at branding (Vision 7, Merck, Kenilworth, NJ). At weaning, heifer calves received 2 doses of Vista once SQ 14 d appart and a 7-way clostridial vaccine with somnus (Vision 7 Somnus, Merck, Kenilworth, NJ). Heifer calf BW was collected at birth, pre-breeding and weaning. An adjusted 205-d weight was calculated without adjustments for dam age. Cow-calf pairs grazed upland range pastures and sub-irrigated meadows from calving until weaning.

Post-weaning heifer management

After weaning, heifers were managed together within their respective breeding group. March born heifers were managed within one pasture and May born heifers were managed in a single separate pasture. March-born heifers grazed sub-irrigated meadow pastures during the winter and were moved to upland range pastures in June prior to breeding. May-born heifers grazed upland range pastures continuously. Heifer BW was collected overwinter, at pre-breeding, pregnancy diagnosis, and pre-calving. Heifer BCS (1 = emaciated, 9 = obese; Wagner et al., 1988) was also collected at pregnancy diagnosis and pre-calving by an experienced technician using visual appraisal and palpation. Pubertal status of the heifers was determined by collecting 2 blood samples 10 d apart approximately 15 d prior to the breeding season as described by (Beard et al., 2019). Heifers were exposed to bulls for a 45-d breeding season with a bull to heifer ratio of 1:20. The same bulls were used in both the March and May-calving herds. Breeding was conducted in one pasture for each breeding season. Bull selection was based off reduced birth weight and moderate potential for growth. Heifers were synchronized with a single shot of $PGF_{2\alpha}$ (5 mL i.m.; Lutalyse, Zoetis, Parisippany, NJ) 5 d after bulls were introduced to pastures for breeding. Pregnancy diagnosis was conducted 40 d after the breeding season via transrectal ultrasonography (ReproScan, Beaverton, OR). A 21 d calving interval was calculated with the start of the calving season coinciding with the first day 2 or more heifers calved.

Statistical Analysis

All analyses were performed using SAS 9.4 PROC GLIMMIX (SAS, Cary, NC). Only records of heifers produced by dams 5 years or older were included in the analyses. To account for differences in both season of calving (March or May) and differences among years, a SEASONYR term was determined. The initial model included the fixed effects of linear adjusted dam BW at weaning, linear heifer birth weight, and linear heifer Julian birth date and the random effects of dam BW by SEASONYR, heifer birth weight by SEASONYR, and heifer birth date by SEASONYR and residual error. Adjusted dam body weight at weaning, heifer birth weight, and heifer birth date terms were tested over the random interaction effect with SEASONYR. Non-significant heifer birth weight and birth date terms ($P > 0.05$) were dropped to produce the final model. A Normal distribution was assumed for all measures, except for heifer pregnancy rate and heifer puberty, where a binomial distribution was assumed. Binomial data was evaluated using odds and odds ratios. Odds (*0*) are the probability of heifers becoming pregnant or pubertal (p) over not being pregnant or pubertal ($1\text{-}p$) as dam BW increases. Odds ratios included in a 95% confidence interval were considered insignificant. When evaluating the influence of adjusted cow BW at weaning on the pubertal status of heifer progeny, the linear effect of heifer birth date would not converge, so it was not included in the analysis. Level of statistical significance was determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

Heifer pre-weaning performance

As adjusted dam BW increased by 100-kg, heifer BW at birth increased by 1.14 kg ($P < 0.01$; Table 3.1). Average heifer birth BW and adjusted 205-d weights were 35 and 213 kg respectively. Similarly, heifer adjusted 205-d weights were increased 4.39 kg ($P < 0.01$) for every additional 100-kg increase in dam BW. Heifer progeny from larger cows may have had an increase in growth potential as growth traits are highly heritable (Nephawe et al., 2004). In support of the current study, Beck et al. (2016) reported an increase of 19 kg of calf weaning weight for each additional 100-kg increase in cow BW. Stewart and Martin (1983) reported if the objective is to maximize weaning weight, the optimal cow size was 493 kg. However, efficiency could be maximized in cow-calf production that optimized growth and reproduction traits simultaneously. In doing so, Stewart and Martin (1983) suggested optimal cow size range from 465 to 493 kg when longevity, number of calves produced, total calf weight, average calf weight at weaning and calf weight per year in the herd were considered.

Heifer post-weaning performance

After weaning, heifer BW increased ($P < 0.01$; Table 3.2) 4.29 kg for every 100-kg increase in dam BW. Heifer BW at the start of the breeding season increased ($P < 0.01$) 4.99 kg for every 100-kg increase in dam BW. Heifer BW prior to calving was increased ($P < 0.01$) 5.94 kg with every additional 100-kg increase in dam BW.

Body condition score of the heifers at pregnancy diagnosis was increased 0.02 BCS ($P < 0.04$; Table 3.2) with every additional 100-kg increase in dam BW. Although BCS increased in heifers from larger dams, the biological relevance of the increased BCS at pregnancy diagnosis is likely minimal due to the small numerical increase. However, heifer BCS measured prior to calving was not ($P = 0.91$) affected by dam BW. This may be due to changes in forage quality grazing dormant pastures post-weaning and the ability for small-framed heifers to gain condition more easily compared with larger heifers (Vargas et al., 1999)

Heifer reproductive performance

In the current study, the odds of heifers achieving puberty prior to the breeding season was not influenced ($P = 0.99$; Table 3.3) by increasing dam BW. The influence of pre-weaning average daily gain has been reported to decrease the number days to attain puberty. Wiltbank et al. (1966) reported the age at puberty decreases 18.7 days for each 0.1 kg increase in average daily gain from birth to weaning. The conversion of the regression coefficients into scale of measure are reported in table 3.4. The likelihood of heifers becoming pubertal prior to the breeding season was not influenced by increasing dam BW 100-kg (67%; $P = 0.99$) Lestmeister et al. (1973) suggested beef replacement heifers need to attain puberty by 12 mo old, conceive at 15 mo old and calve as 2-yr-olds. Therefore, the timing and onset of puberty is critical in the efficiency of production (Hall et al., 1995). In contrast to the current study, Short and Bellows (1971) reported a greater number of heifers reaching puberty as BW increased linearly. In a review, Patterson et al. (1992) suggested that heifers with greater BW at 6 mo of age reach puberty at younger ages and greater BW at 6 mo of age lead to heavier BW at first calving. Vargas et al. (1999) reported that small- and medium-framed heifers achieved puberty at a younger age than large-framed heifers. Our data suggests that dam BW and growth differences in heifer progeny did not influence heifer progeny pre-breeding puberty status.

In the current study, increasing dam BW was not significant in determining if heifers would become pregnant ($P = 0.11$; Table 3.3) or the number of heifers calving in the first 21 d of the calving season ($P = 0.91$). The percent of heifers becoming pregnant as dam BW increased was not influenced by increasing dam BW 100-kg (80 vs 85%; $P = 0.11$; Table 3.4). The percent of heifers calving in the first 21 d was similar as dam BW increased 100-kg (78 vs 79%; $P = 0.91$; Table 3.4). Clanton et al. (1983) reported that heifers developed with a constant rate of gain, late gain (increased gain prior to breeding), or early gain (gain more quickly after weaning) had no influence on reproductive success. In support of our data, Vargas (1999) reported no difference in calving date or calving rate between small-, medium-, or large-framed first-parity heifers. Under the management practices of the current study dam BW does not influence heifer progeny reproductive performance as a heifer.

In conclusion, under the production scenario evaluated, results from this study indicate increasing dam BW increases pre-and post-weaning heifer progeny BW with no influence in the likelihood of heifers becoming pubertal prior to breeding, overall pregnancy rates, or calving in the first 21 d. In production, these results may indicate larger cows produce greater heifer progeny weaning weights, which could generate more revenue, and larger-sized heifers could be retained with no detriment in fertility. However, continued selection for increased dam size may reach a point of diminishing returns.

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Table 3.1 Regression coefficients used to evaluate the influence of increasing dam body weight (BW) 100-kg on heifer progeny pre-weaning BW

Body Weight, kg	Estimate	SE	*P*-value
Birth	1.14	0.15	<0.01
Adjusted 205-d	4.39	0.71	<0.01

Table 3.2 Regression coefficients used to evaluate the influence of increasing dam body weight (BW) 100-kg on heifer progeny post-weaning performance

Measurement	Estimate	SE	*P*-value
Body Weight, kg			
Winter	4.29	0.75	<0.01
Pre-breed[1]	4.99	0.91	<0.01
Pregnancy check	6.00	1.00	<0.01
Pre-calving	5.94	1.28	<0.01
BCS[2]			
Pregnancy check	0.02	0.01	0.04
Pre-calving BCS	0.002	0.02	0.91

[1] Pre-breed weights were collected approximately 15 d prior to breeding in June or August depending on calving season

[2] BCS = Body condition score scale of 1 (emaciated) to 9 (obese) (Wagner et al., 1988)

Table 3.3 Regression coefficients use to evaluate the influence of increasing dam body weight (BW) 100-kg on heifer progeny reproductive performance

Measurement	Estimate	SEM	*P*-value
Pubertal status[1]	-0.002	0.09	0.99
Pregnancy rate	-0.16	0.10	0.11
Calving 1st 21-d	-0.01	0.10	0.91

[1] Pubertal status was evaluated by collecting 2 blood samples approximately 15 d prior to the breeding season to analyze progesterone concentrations

Table 3.4 Heifer reproductive regression coefficients converted to scale of measure: Impact of increasing cow body weight (BW) 100-kg

Measurement	Standard BW	100-kg increase BW	SEM	*P*-value
Puberty status[1], %	67	67	0.08	0.99
Pregnancy rate, %	80	85	0.04	0.11
Calving 1st 21-d, %	78	79	0.04	0.91

[1] Puberty status evaluated by collecting 2 blood samples 10 d apart approximately 15 d prior to breeding and analyzed for progesterone concentration

CHAPTER IV: Efficacy of an electronic feeding system designed for supplementing cattle on pasture

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ABSTRACT

Two experiments were conducted to validate the efficacy of an electronic individual animal feeding system designed for supplementing cattle on pasture and evaluated the behavior associated with naive cattle attending the feeding system. In both experiments, a dried distillers grain-based range cube were fed to provide 0.45 kg/hd/d. Period one started the day after cattle were introduced to the feeder until the day prior to gates being lowered (18 and 1 d for experiments one and two respectively). Period two initiated the day after gates where lowered and concluded when cattle were assigned to eat from an assigned tray (3 and 8 d for experiments one and two respectively). Period 3 started when cattle were assigned a specific tray until the trial ended (1 and 2 d for experiments one and two respectively). Experiment 1 was conducted over 23 d using 40 mature pregnant cows age 4- to 8- yr-old in a 39 hectare pasture. Out of the 40 cows, 87.5% went within close enough proximity (approximately 25.4 cm) for the feeder to drop feed, 67.5% used the feeder 3 or more days. Cattle most frequently visited the feeder between 0800 and 0900 during the duration of the trial. Experiment 2 was conducted using 86 first- and second-calf heifers in a drylot during calving. Eighty out of the 86 heifers came within close enough proximity (approximately 25.4 cm) of the feeder to dispense feed. In both experiments, a decrease in ambient temperature tended ($P \leq 0.09$) to decrease supplement intake. In addition, visits to the feeder were increased ($P < 0.01$) when ambient temperature was below average. Time spent at the feeder was not influenced ($P \geq 0.26$) by ambient temperature. Overall, these findings quantify the number of cows that become

accustomed to using the electronic feeding system, how ambient temperature and diurnal rhythms influence feeding patterns and suggested calibration methods when feeding range cubes from a SuperSmart Feeding (C-lock Inc. Rapid City, SD) system.

Keywords: feeding behavior, individual supplementation, precision feeding, technology

INTRODUCTION

Technologies in electronic monitoring systems are focused on physical behavior, feeding systems, and global-positioning systems to increase efficiency and animal welfare (Richeson et al., 2018). As profit margins become thin in animal agriculture, generating the most efficient means of production is critical for sustainability of an enterprise. Common supplementation strategies in livestock production provide supplements to the entire herd or group of cattle creating significant variation of supplement intake for each animal (Wagnon, 1965). The development of a novel individual feeding system designed for supplementing cattle on pasture could reduce labor inputs, feed costs, and variation in supplement intake between cattle and improve animal welfare (Reuter and Moffet, 2016).

The use of electronic cattle monitoring systems has been used in feedlot settings to monitor individual feed intake and in pasture settings to measure supplement intake (Williams et al., 2018; Wyffels et al., 2018; McCarthy et al., 2019). However, a limited number of studies have quantified the acclimation period when naïve cattle are introduced to an electronic feeding system.

Therefore, the objective of this study was to evaluate feeding behavior when naïve cattle were introduced to a novel electronic feeding system designed to supplement cattle on pasture and evaluate the influence ambient temperature has on feeding behavior.

MATERIALS AND METHODS

Materials and methods used in this experiment were in accordance with the University of Nebraska-Lincoln institutional animal care and use committee.

Both experiments were conducted at the Gudmundsen Sandhills Laboratory (GSL) located near Whitman, NE. The breed composition of the cattle utilized were Husker Red (~5/8 Red Angus, 3/8 Simmental). All cattle were fitted with an electronic identification (EID; Allflex USA Inc., Dallas, TX.) tag prior to the initiation of the trial in their left ear.

The electronic individual feeding system was a Super SmartFeed (SSF; C-Lock Inc., Rapid City, SD.). The SSF is a self-contained feeding system designed to record individual feed intakes, and frequency of visits to the feeder designed for pasture use. By design, the SSF has gates that can be lowered to ensure a single animal has access to feed at one time in efforts to avoid crowding and competition for feed. At the initiation of both experiments, the SSF was leveled using provided jacks and the solar panel was oriented pointing south and angled approximately 29°. The feed bin was calibrated using a 22.68 kg weight. The feed trays were calibrated using a 2 kg weight and the amount of feed drop were initially calibrated using the average of 20 ticks in experiments one and two. Calibration results from experiment 2 are reported in (Table 4.1). The average of the 20 ticks was the value recorded in GreenFeed so the SSF would provide 0.45 kg to each animal daily. Daily supplement allotment for the cows were reset at 0000 hr each day. Electronic identification tag proximity sensors on the SSF were set to dispense feed when an EID tag was detected within 25.4 cm.

The supplement (SUP) fed during both experiments was a dried distillers grain based range cube (Farmers Ranchers Co-op, Ainsworth, NE). Range cubes were approximately 6.35 cm in length and 2.54 cm in diameter. The nutrient profile of the SUP is reported in table 4.6. A 50% salt 50% di-calcium phosphate mixture was fed *ad libitum* in the trays of the feeder to attract cattle. Temperature data was collected daily using a High Plains Regional Climate Center weather station. Daily temperatures were considered above or below according to the past 35 yr average.

Experiment 1: Experiment one was conducted using 40 mature cows age 4 to 8- yr old in a 39 hectare pasture. On d -2 all cows were individually weighed, body condition scored (BCS1 = emaciated, 9 = obese: Wagner et al., 1988) by an experienced technician using visual appraisal and palpation over the ribs, vertebrae, and hind quarters. Electronic identification tags were scanned using a handheld tag reader to verify all tags were functioning properly (RS420, Allfex USA Inc., Dallas, TX.). Approximately 159 kg of SUP was placed in each of the 4 bins of the SSF (636 kg total). Cows were introduced to the pasture on day 0 where the SSF was placed. Meadow hay was fed at approximately 1000 hr to the cows daily for the first week of the trial within 30 meters the SSF. For the remainder of the trial, hay was fed every-other day within 100 meters of the SSF.

On d 0, 23 kg of the SUP was scattered within 5 meters of the feeder and 0.45 kg was placed in each of the 4 trays to attract cattle to the SSF. Two technicians on all-terrain vehicles held the cattle within 50 meters of the SSF for 20 min. Period 1 started on d 1 and concluded on d 17.

On day 2 of the trial, a pickup truck with an audible siren was used to attract cattle to the SSF. Additionally, on day 2, 23 kg of SUP was scattered within 10 meters of the feeder to attract cattle.

On day 4-7, 11, and 16 of the experiment 23 kg of the SUP was scattered on the ground in a circle within 1 meter of the SSF to attract cattle (bait). On days 4, 11, and 16, cattle that received SUP from the SSF 3 or more times were sorted from the herd and penned in a coral during baiting sessions and returned to the pasture approximately 3 hours later (3, 10, 20 head, respectively). While the cattle were around the SSF on d 4, 0.45 kg of the SUP was dispensed into each tray remotely to acclimate the cattle to the sound of SUP dropping into the trays of the SSF. Five minutes later, while cattle were still surrounding the feeder, another 0.45 kg were dispensed remotely into each of the 4 trays of the SSF. While cattle were surrounding the feeder on d 5, a technician used the keypad on the side of the SSF to dispense 0.45 kg of the SUP into each of the 4 trays. A 50% salt 50% di-calcium mixture (1.8 kg) was added to each of the trays on d 5 as an attractant. For the remainder of the trial, mineral was replenished daily.

Period two started on d 18 and concluded on d 21. Gates on the SSF were lowered on d 18 to prevent cattle from competing for SUP and ensure the SUP that was dispensed was consumed by one individual cow. Period 3 started on d 22 and concluded on day 23 due to technical difficulties. All cows in the pasture were assigned to receive SUP from a specific tray on day 22. Cattle were assigned to each tray based on age so each tray had similar numbers of 4-yr, 5-yr, 6-yr, 7-yr, and 8-yr old cows. After a 10 d adaptation period ambient temperature affects were evaluated on supplement intakes.

*Experiment 2***:** In order to accelerate the acclimation period for experiment two, fifty-one first-calf heifers and 35 second-calf heifers were baited to a creep feeder 3 times per week for 19 d prior to being introduced to the SSF. The creep feeder was located in an 82 hectare pasture. Twelve kg of the SUP was scattered on the ground within 2 meters of the creep feeder and 11 kg of the SUP was placed in the trays of the creep feeder. The same mineral used in experiment one was fed *ad libitum* in the creep feeder all 19 d.

Heifers were relocated to a 1 hectare drylot on d -9. Hay was fed in the calving lot at 1600 hour daily throughout the duration of the experiment. The SSF was placed in the drylot on d -6. At this time, the SSF was baited with 23 kg of SUP scattered on the ground within 2 meters of the SSF. The same mineral that was used in the creep feeder was placed in each of the 4 trays and 0.45 kg of SUP to attract the heifers to the SSF. Mineral was fed for the duration of the experiment *ad libitum* from each of the trays of the feeder. The SSF allowed the heifers' access to SUP on d 0. Period 1 and data collection started on d 1 and ended on d 2. Day 3 was the start of period 2 when the gates on the SSF were lowered to ensure individual SUP intake. Period 2 ended on d 10. Period 3 started on d 12, heifers were randomly assigned to receive SUP from 1 of the 4 trays according to age to ensure each tray had a similar number of fist- and second-calf heifers. Each tray was assigned a feed dispense speed, similar to experiment one. After calving, heifers were removed from the drylot and experiment 2, period 3 concluded on d 13.

STATISTICAL ANALYSIS:

Data were analyzed using PROC MIXED of SAS (SAS, Gary, NC). PROC CORR was used to evaluate the influence of supplement intake on cow body weight change and body condition score change. Individual animal was considered the experimental unit. Tendencies were declared when $P \leq 0.10 > 0.05$ and significance at $P \leq 0.05$.

RESULTS

Calibration Method

The weight of supplement dispensed when using the manufacture recommended settings and settings recommended by GSL is reported in table 4.2. Weights in feed collected between the two methods at bin 1 were significantly different ($P = 0.01$) 0.16 and 0.56 kg for the manufactured recommended calibration method and the GSL method, respectively. Weight of feed collected at Bins 2 and 3 tended to be different ($P \leq 0.08$) between the two calibration methods and bin 4 was not different ($P = 0.93$) most likely because the manufacture calibration method was set to dispense 3 clicks using the average of 20 ticks. Considering the average difference in weight collected from the 0.45 kg daily allotment, the GSL recommended calibration method was significantly closer ($P = 0.02$) to 0.45 kg compared to the manufacture recommended method

0.08 and -0.14 kg respectively. The average weight of feed samples using collected during the duration of both experiments is shown in figure 4. 4. The range in weight of feed dispensed ranged from 0.33 to 0.57 kg in experiment one between the 4 bins. In experiment two, the weight of feed dispensed between all four bins was 0.38 to 0.46 kg.

Experiment 1

Throughout the duration of the trial, 35 out of the 40 (87.5%) cows in Exp. 1 came within 25.4 cm to the SSF EID tag reader and feed was dispensed. Twenty-seven out of 40 (67.5%) cows used the feeder 3 or more days during the trial. During period 2 when gates on the SSF were lowered, the greatest number of cows using the feeder was 18 (45%). During period three, when cows were assigned to eat from specific trays, 10 cows used the SSF (25%). Five cows did not use the feeder over the duration of the trial (13%).

The correlation of supplement intake level and change in cow BW and BCS are reported in table 4.4. Body weight change was not influenced by supplement intake level (P = 0.51). Additionally, supplement intake did not influence change in BCS (P = 0.49) over the duration of the trial. Considering the short duration of the trial and amount of supplement offered, BW and BCS change was not anticipated.

Cows most frequently visited the SSF between 0800 and 0900 hr and visited the SSF the least between 2000 and 2100 hr (Figure 4.1). Average supplement intake when ambient temperature was above or below the 35 yr average tended (P = 0.08; Table 4.3) to be influenced by temperature. Visits to the feeder were significantly different according to ambient temperature ($P < 0.01$). However, the length of time (min) cows spent at the feeder was not influenced by ambient temperature ($P = 0.53$).

Experiment 2

In experiment 2, 80 out of the 86 (93%) heifers introduced to the feeder came within 25.4 cm for the SSF EID tag reader to drop feed. Fifty-nine out of the 86 (69%) heifers activated the feeder during period 1 prior to the gates mounted on the SSF were lowered. Sixty-eight (85%) heifers activated the feeder during period 2 when the gates were in place. Fifty-one heifers activated the feeder during period 3 after they were assigned to specific trays. Six heifers did not use the feeder during the entire trial (7%). The hour with the greatest number of total visits was between 0700 and 0800 (Figure 4.2), whereas, the hour with the least number of visits was between 0400 and 0500.

Ambient temperature effects on supplement intake (kg), number of visits, and minutes spent at the feeder are reported in table 4.4. There was a tendency for heifers to consume more supplement on days that were above the average temperature ($P = 0.09$). The number of visits to the feeder were also greater on days below average ambient temperatures ($P < 0.01$). The minutes spent at the feeder where not influenced by ambient temperature ($P \geq 0.20$).

DISCUSSION

Large differences in the amount of feed dispensed in each tray was observed when collecting daily samples from the SSF, largely due to the fact that 3 of the 4 bins where dispensing 2 clicks while one of the bins was dispensing 3 clicks using the manufactured recommended calibration. The GSL suggested recommendation for calibration was to set all bins to drop 3 clicks for the 0.45 kg per head per day allotment. It is likely the size and structure of the range cube supplement resulted in inconstant daily supplement delivery. The feed is gravity fed out of the bin onto a conveyor belt. The distance between the bottom of the bin and the belt is approximately 8.89 cm. Therefore, large bulky feeds are not easily or accurately dispensed daily. When samples were averaged across several days using the manufactured recommended calibration, the target daily feed allotment was relatively close to the targeted daily allotment of 0.45 kg. But less variation in supplement delivery between trays was observed using the GSL recommended calibration method. Further studies would need to be conducted to determine if smaller more fine feed would be more accurately measured.

When considering the number of eaters and non-eaters, it is important to consider the short period of time cows were introduced to the feeder in both experiments. A longer trial may increase the number of cattle accustomed to the feeder. Cattle often experience neophobia when exposed to new feeds (Launchbaugh, 1995). Although the cows utilized in the experiment were familiar with the supplement offered, it is likely the SSF caused neophobia. In feedlot cattle, neophobic eating patterns usually last less than 2 weeks (Hicks et al., 1990). In experiment one, 13% of the cows were considered non-eaters over a 23 d trial. Coombe and Mulholland (1983) reported sheep not consuming supplement for up to 8 weeks after exposure to supplements. Considering the short period of time cattle were introduced to the SSF, we consider 12% was a relatively low percent of non-eaters. Bowmen and Sowell (1997) reported the number of non-feeders when livestock were offered hand-fed supplements to be 5%. It is likely sorting off cattle that were routinely visiting the feeder and baiting the naive cows to the feeder helped acclimate naïve cows. However, in large pasture settings, sorting cattle into corals routinely is likely unrealistic, unless corrals are readily available. In experiment 2, 7% of the heifers were non-eaters. It is likely introducing the heifers to a creep feeder for one month prior to the SSF helped reduce neophobia. Additionally, the heifers were contained in a 1 hectare drylot keeping them close to the feeder and may have accelerated the acclimation period compared with the 40 hectare pasture utilized in experiment one.

Cows most frequently visited the feeder over the 0800 to 0900 hour in experiment 1 and 0700 to 0800 in experiment 2. These results are similar to Williams et al. (2018a) where authors reported cattle most frequently visiting an electronic feeder between the hours of 0800 to 0900 during grazing dormant winter range pastures. Putnam and Bond (1971) reported spring-calving cows in a drylot feeding the most between the hours of 1500 and 1800 and a decrease in the time spent at the feeder prior to and after calving. We noticed an increase in the number of visits during experiment 1 at 1300-1400 hr. This is likely due to the stimulus of technicians collecting feed samples at that hour attracting the cows. Williams et al. (2018a) reported similar results when technicians replenished feeders. During experiment two, samples were collected around 0700 when cattle were frequently visiting the feeder, so the stimulus of sample collection could have influence the number of heifers visiting the feeder at 0700 to 0800. We also noticed a large number of visits between 0000 and 0100 h, approximately 20 and 150 in experiments one and two respectively. These observations are likely due to the daily supplement reset allotment occurring after the midnight hour. However, during an overnight snow event, minimal activity at the feeder was detected overnight (Figure 4.3).

In both of the current experiments, ambient temperatures below average tended to decrease supplement consumption. Wyffels et al. (2018) reported ambient temperatures influenced supplement intake in cows ranging from 1-yr to 8-yr old. As ambient temperature decreased, younger cows increased intake as ambient temperature decreased, whereas older cows decreased supplement intake as ambient temperature decreased. Adams et al. (1986) reported a decrease in grazing time as ambient temperature decreased. Difference in grazing time and time consuming supplement as ambient temperature decrease could be a mechanism for cattle to lower energy requirements. Ambient temperature also influenced the number of visits to the SSF with more visits occurring when ambient temperature was below average. The visits to the feeder in experiment one were similar to the number of visits reported by Wyffels et al. (2018) reported for cows grazing dormant winter range. However, in experiment 2 the number of visits to the feeder where greater than most reported in the literature. This could be due to the fact that visits in the current study were counted when an EID tag was detected, which could have inflated the actual number of visits cows were at the feeder. Head movements could have caused the EID to be detected several times within the same visit to the feeder. Williams et al. (2018) reported visits ranging from 30-35 for cows in a drylot. Differences in the number of visits between the two studies could be attributed to difference in cow age. Ambient temperature did not influence time spent at the feeder in both experiments.

Results from the current study provide insight on the acclimation period of cattle introduced to an electronic feeding system. Sorting cattle that are accustomed to the feeder and baiting naïve cattle to the feeder seems to accelerate the acclimation period if pens are available. Keeping the feeder and cattle in a more confined area may also help cattle become accustomed to novel electronic feeding systems or close to water sources. Understanding supplement intake requirements according to ambient temperature or cold stress could improve efficiency by providing cattle supplement only when necessary. The ability to set a specific amount of supplement to individual animals could increase the efficiency of supplements and reduce variation in intakes.

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Table 4.1 Calibrating feed drops recommended by manufacture and the Gudmundsen method to dispense 0.45 kg per day

Tray	20 click wt. kg.[1]	Kg per click[2]	Clicks[3]	Average, kg[4]
1	3.36	0.17	2	0.19
2	3.08	0.154	2	0.41
3	3.04	0.152	2	0.36
4	2.72	0.114	3	0.55
Gudmundsen settings				
Tray				
1	-	0.1511	3	0.56
2	-	0.1511	3	0.52
3	-	0.1511	3	0.44
4	-	0.1511	3	0.47

[1] Weight of supplement collected after dispensing 20 clicks
[2] Kg per click set in online interface to dispense 0.45 kg per day
[3] Number of clicks to dispense 0.45 kg per day when an animal approaches feeder
[4] Average weight of supplement collected by technician during calibration procedure

Table 4.2 Differences in calibration recommended by manufacture and suggested by Gudmundsen when feeding range cubes: Samples collected using electronic identification tags

Tray	Recommended[1]	Suggested[2]	SEM	*P*-value
1	0.16	0.56	0.08	0.01
2	0.33	0.53	0.08	0.08
3	0.28	0.54	0.09	0.06
4	0.46	0.47	0.09	0.93
Difference from 0.45kg[3]	-0.14	0.08	0.05	0.02

[1] Weight of feed collected over 5 d using recommended calibration method suggested by manufacture dispensing 20 clicks
[2] Weight of feed collected over 5 d using Gudmundsen recommended setting all bins to dispense three clicks
[3] Difference in average weight dispensed from 0.45 kg

Table 4.3 Influence of ambient temperature above or below 35 yr average[1] on intake, number of visits, and time spent at the feeder: Exp 1

Measurement	Above	Below	SEM	*P*-value
Intake, kg	0.34	0.27	0.03	0.08
Visits[2]	12.7	28.8	4.29	<0.01
Minutes[3]	6.14	5.25	1.40	0.53

[1]Thirty-five year average temperature was -3.05^{oc} in the months of the current study
[2] Average number of visits to the feeder
[3] Time spent at the feeder in minutes

Table 4.4 Correlation of supplement intake level and change in cow body weight (BW) and body condition score (BCS)

Measurement	Coefficient	*P*-value
Change in BW	-0.116	0.51
Change in BCS	-0.119	0.49

Table 4.5 Influence of ambient temperature above or below 35 yr average[1] on intake, number of visits, and time spent at the feeder: Exp. 2

Measurement	Above	Below	SEM	*P*-value
Intake, kg	0.25	0.21	0.02	0.09
Visits[2]	22.3	98.9	7.29	<0.01
Minutes[3]	10.7	9.08	1.00	0.26

[1] Thirty-five year average temperature was 0.28°c during the experiment
[2] Average number of visits to the feeder
[3] Time spent at the feeder in minutes

Table 4.6 Nutrient profile of supplement used to validate an electronic feeder (As fed)

Dry Matter, %	90.41
Crude Protein, %	29.82
Non-protein nitrogen, %	4.15
RUP[1], (%CP)	39.65
RDP[2], (%CP)	60.35

[1] Rumen undegradable protein
[2] Rumen degradable protein

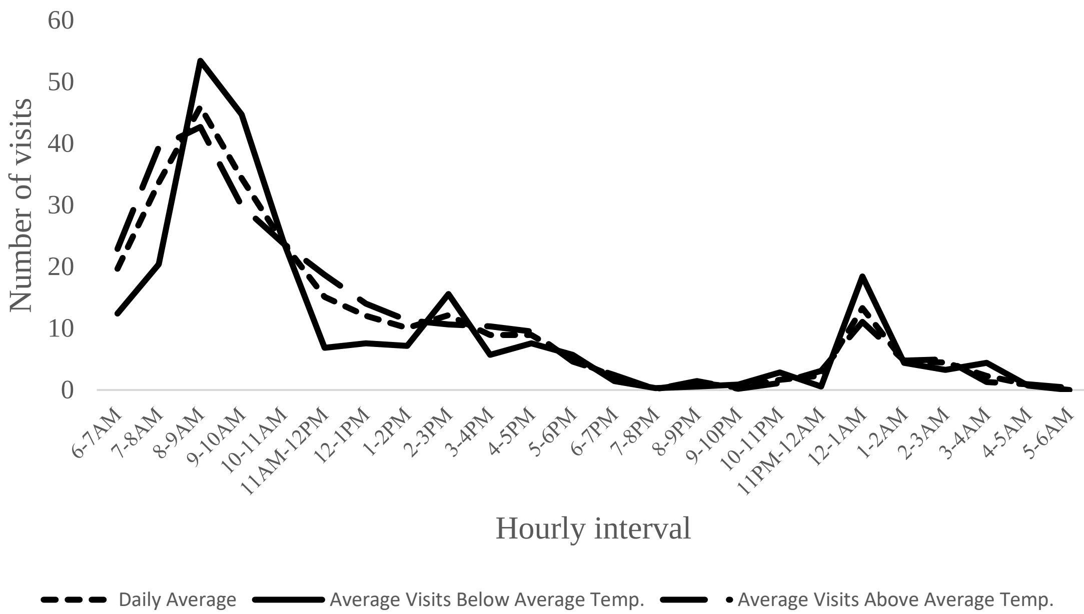

Figure 4.1 Average number of visits cows visited the feeder across 24 hours for the duration of the trial. Thirty-five year average ambient temperature was -3.05°c

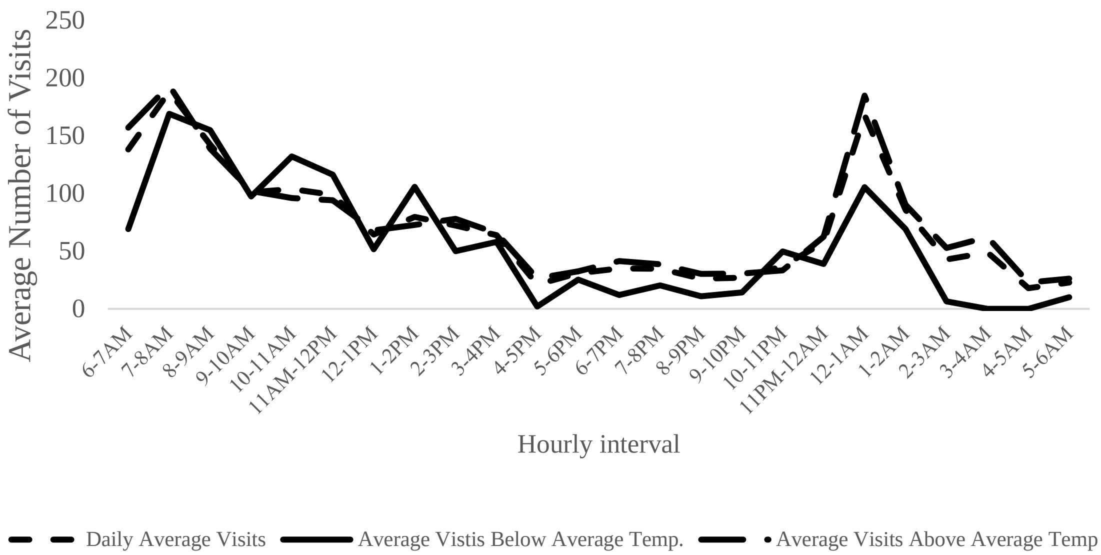

Figure 4.2 Average number of visits heifers visited the feeder across 24 hours for the duration of the trial. Thirty-five year average ambient temperature was 0.28°c over the trial duration

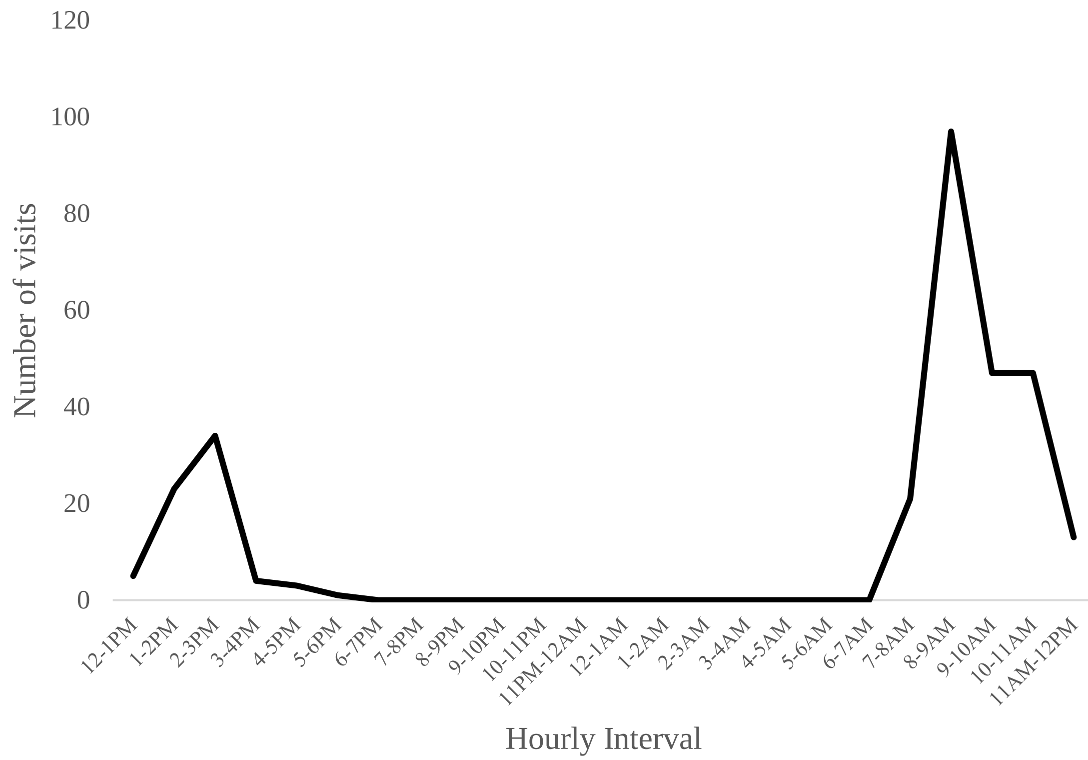

Figure 4. 3: Number of visits cows approached an electronic feeding system during a 24 hour period with snow accumulations of 5 cm overnight

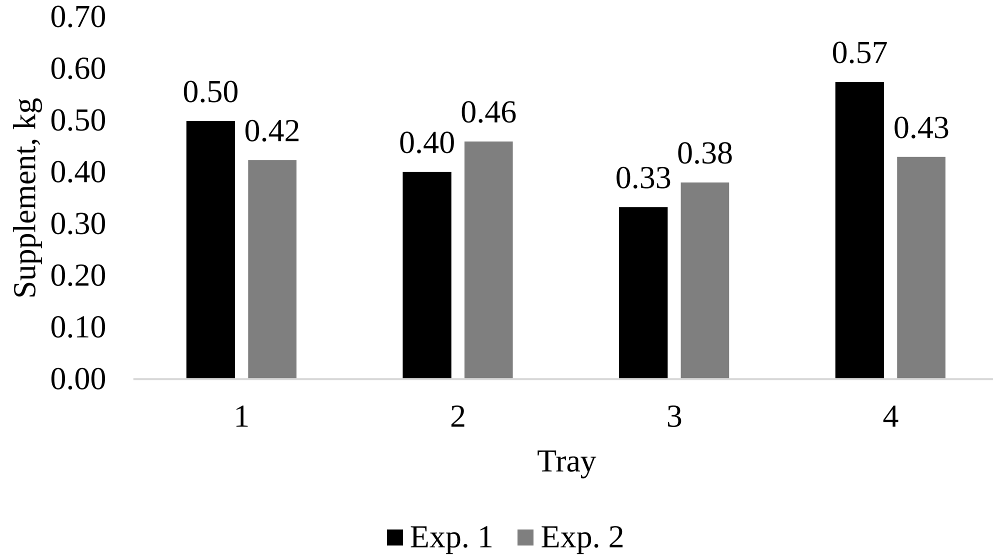

Figure 4.4 Average weight of feed samples collected during two experiments used to evaluate the efficacy of an electronic feeder used to supplement pasture cattle

CHAPTER V: Summary, recommendations, and conclusions

Research described in this thesis was part of the University of Nebraska-Lincoln strive to improve beef cattle production efficiency. Optimizing efficiency of resources by selecting for animals that excel in their production environment is critical to improving production efficiency. Selection pressure for growth potential has caused an increase of the mature cow size. Being cognizant of matching cow size with available resources is critical to efficiency. Furthermore, when supplementation is warranted to the cow herd, improving the utilization of the supplement can improve efficiency. Previous methods of supplement delivery are supplied to the entire herd creating competition which leads to over, or under consumption of supplement between livestock in the herd. Optimizing efficiency through proper selection of cows that excel in their environment and innovative supplement delivery systems may improve efficiency of the cow-calf enterprise.

The first study evaluated the influence of increasing cow size 100-kg on cow and steer progeny performance in the Nebraska Sandhills. The impact of increasing cow size on performance varies drastically between production environments and has not been previously evaluated in the Nebraska Sandhills. Cows of larger body weight (BW) had improved BW change during the breeding season and increased pregnancy rates. Steer progeny had increased BW throughout the entire beef production system and minimal influence on carcass quality. However, measuring efficiency favored cows of smaller size. The ability to stock more cow-calf pairs in a fixed pasture space increased economic returns and total output at weaning and slaughter when smaller cows are utilized.

The second study evaluated the impact of increasing dam size on heifer progeny performance. Heifer development is a costly endeavor for cow-calf producers. Understanding how mature dam size impacts heifer development could increase cow-calf efficiency. Results from the study indicate that increasing dam size increased heifer progeny pre- and post-weaning BW with no impact on heifer reproduction. Selection for increased mature dam size should be evaluated with caution as over selecting for growth potential has diminishing returns on total production output.

The third study evaluated the efficacy of an electronic feeder designed to supplement cattle on pasture. Reducing the amount of labor to deliver supplements and minimizing variation in supplement intake between animals could improve efficiency of inputs. Results from this study indicate 13% of cows not consuming supplement from the feeder and 7% of heifers not using the feeder. Additional results indicate supplement intake decreases as ambient temperature decreases. A better understanding of matching supplemental levels with environmental stress and reduced variation between animal supplement intake levels could improve efficiency of delivering supplement at critical times.

Overall, this thesis highlights two strategies cow-calf producers could utilize to improve efficiency. These studies highlight the opportunity to increase total output by selecting for the cow type that optimizes resources, and an innovative supplement delivery system that could improve supplement efficiency.